Civil & Commercial Applications Project (CCAP): Evaluation of Imagery Interpretability for IKONOS Pan, MSI, and Pan-Sharpened Imagery

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High Spatial Resolution Commercial Imagery Workshop

Study Objectives

- Characterize the interpretability of IKONOS imagery in order to allow military and intelligence users to confidently purchase IKONOS imagery with some understanding of its utility

  – Provide a range of Visible National Imagery Interpretability Rating Scale (NIIRS) ratings for IKONOS Pan imagery

  – Provide a range of Multispectral Imagery Interpretability Rating Scales (MS IIRS) ratings for IKONOS MSI and Pan-sharpened imagery

  – Provide additional quantification of the capacity of IKONOS Pan, MSI and Pan-sharpened imagery to provide intelligence information to the Imagery Analyst (IA) through Essential Elements of Information (EEI) task satisfaction

Imagery Requirements

- An imagery matrix was developed that ensured collection of targets that met requirements of the:
  - Community Imagery Needs Forecast (CINF)
  - Where possible, for image tasks that comprise the Visible NIIRS and MS IIRS criteria
- A distribution of targets from across four climatic regions were tasked and received
  - Arid (10)
  - Tropical (9)
  - Temperate North (9)
  - Temperate South (8)

Imagery Used

- Evaluation of Pan imagery initiated before imagery matrix was complete
  - 39 images used to create 72 image chips
    - 24 Level 1 TIFF formatted images from vendor
    - 15 Level 2 GeoTIFF formatted images from DoD archive
  - Mean GSD ranged from 0.82 m to 1.30 m

- Evaluation of MSI and Pan-sharpened initiated upon fulfillment of imagery matrix
  - 32 Level 1 MSI scenes used to create 128 image chips
  - 12 Level 1 Pan-sharpened scenes used to create 30 image chips
  - Mean MSI GSD ranged from 3.28 m to 4.95 m
  - Mean Pan-sharpened GSD ranged from 0.82 m to 1.17 m

Approach

- Each IA provided a NIIRS/MS IIRS rating for each image chip

- IAs were also asked to provide their confidence in being able to perform certain tasks on imagery of the quality presented to them

- These task satisfaction questions solicited the analysts' confidence, on a 0 to 100 scale, in their ability to perform an image interpretation or EEI task
  - Multiple questions for every scene
  - Each question asked for up to six different scenes
  - Questions chosen based on the Order of Battle (OB) present in the image

Ratings Scales

- ## NIIRS
  - Graduated 10 point scale (0-9)
  - Provide a standard measure of interpretability for the imagery
  - Quantifies the interpretability of an image based on the types of exploitation tasks that can be performed. The NIIRS ratings collected in this evaluation provide a link to studies of other Panchromatic systems

- ## MS IIRS
  - Graduated 8 point scale (0-7)
  - Quantifies the interpretability of an image based on the levels of exploitation tasks that can be performed

Intelligence Task Satisfaction

- An EEI represents a request for intelligence information
  - In addition to using the spatial characteristics of image observable criteria for the EEI, the color qualities of the observable might also be addressed

- EEI are derived from a variety of sources
  - NIIRS, MS IIRS and Civil NIIRS criteria, which are listed by their respective IIRS level
  - CINF

- The EEI were restated in terms of image observables and related tasks
  - The EEI chosen for the Pan evaluation addressed image tasks for NIIRS levels 3 through 6
  - The EEI chosen for the MSI and Pan-sharpened evaluation addressed image tasks for MS IIRS levels 2.0 through 5.8

Methodology

- Conducted at NIMA/ASAI's softcopy evaluation facility
  - Separate evaluations for Pan and MSI/Pan-sharpened
- All evaluation participants used the same workstation with a calibrated precision color monitor
  - Minimum luminance response of 0.10 fL
  - Maximum luminance response of 35.0 fL
- Participants were free to roam and zoom at 1X or 2X magnification within the image
- All ratings were made at 2X
- No interactive enhancement of the imagery was allowed, and all preprocessed evaluation image chips were rendered with no additional processing

Analysis: Pan

- Eight IAs completed the Pan evaluation over an eleven-day period
  - 72 NIIRS ratings
  - 250 confidence ratings of EEI tasks
- High degree of consistency among the raters
  - The rater-group correlations ranged from 0.68 to 0.75 and the alpha was 0.89
- Analysis of Variance: outliers
  - One image was removed from the NIIRS data set
  - Two images were removed from the EEI confidence ratings
- Analysis of covariance
 - Analysis revealed that format was not a significant main effect

Pan NIIRS

- $Log_{10}GSD$ ($\underline{p} = .02$) and the interaction term ($\underline{p} = .07$) are significant predictors of NIIRS ($R^2 = .19$)
- Climate dropped (not significantly different)
- Format does not directly impact NIIRS ratings
  - The 0.24 difference in mean NIIRS between TIFF and GeoTIFF formats is based on the average differences in GSD and the interaction between GSD and format
    - TIFF GSD (.931meters)
    - GeoTIFF (.993 meters)
- Mean NIIRS of 4.5
  - TIFF NIIRS of 4.65
  - GeoTIIF NIIRS of 4.41

Image Quality Equations

- Regression driven equations with limited terms
- GeoTIFF predicted NIIRS = $4.41 - 0.77 * \log_{10} GSD$
- TIFF predicted NIIRS = $4.52 - 5.05 * \log_{10} GSD$
- The predicted NIIRS is the same for both formats at a GSD of 1.06 meters

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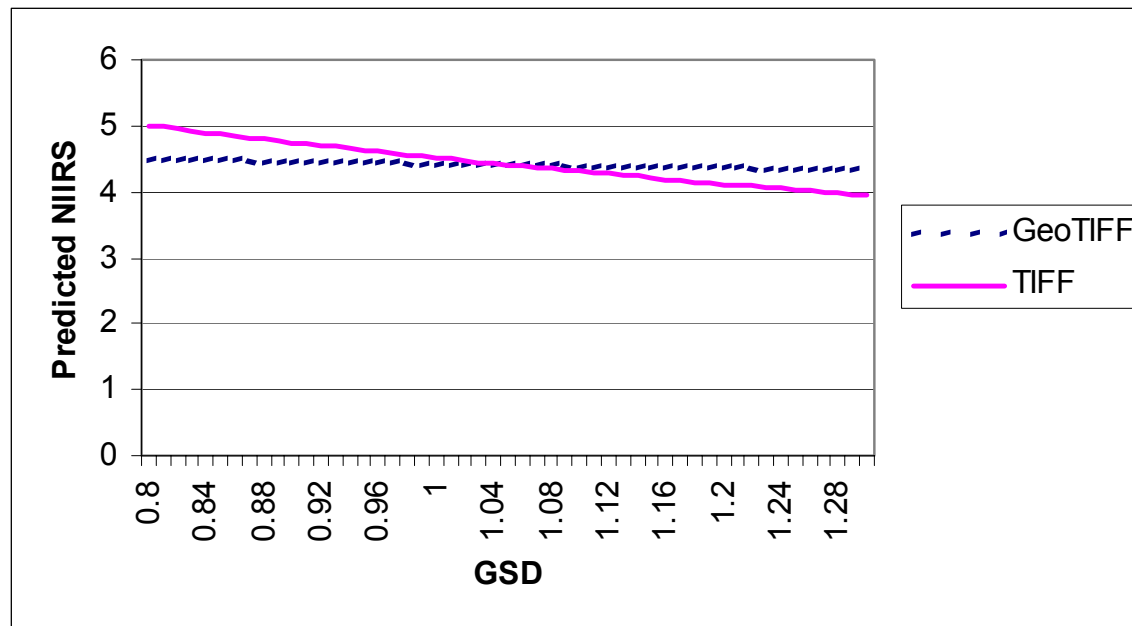
IQE Analysis

- Slope for the TIFF equation is much steeper than a General Image Quality Equation calculated slope of -3.32
  - 95% confidence interval includes -3.32, indicating that GSD is a significant predictor of NIIRS ratings for TIFF imagery
  - 95% confidence interval for GeoTIFF regression slope includes zero, indicating GSD may not be a significant predictor of NIIRS for GeoTIFF imagery
- Slope of zero not unreasonable for imagery resampled to a uniform GSD
  - Can only be true over a very limited range of GSDs
- An image with a collected GSD of two meters that has been resampled to one meter would not be expected to be as good as an image with a true GSD of one meter
  - Hypothesized that an IQE over a larger range of GSDs would be a broken line with two slopes, with the break occurring at or near one meter
  - The slope for GSDs less than one meter would be zero or possibly somewhat negative
  - The slope of GSDs greater than one meter would be comparable to Panchromatic imagery characterized by the GIQE, i.e., about -3.31 or so
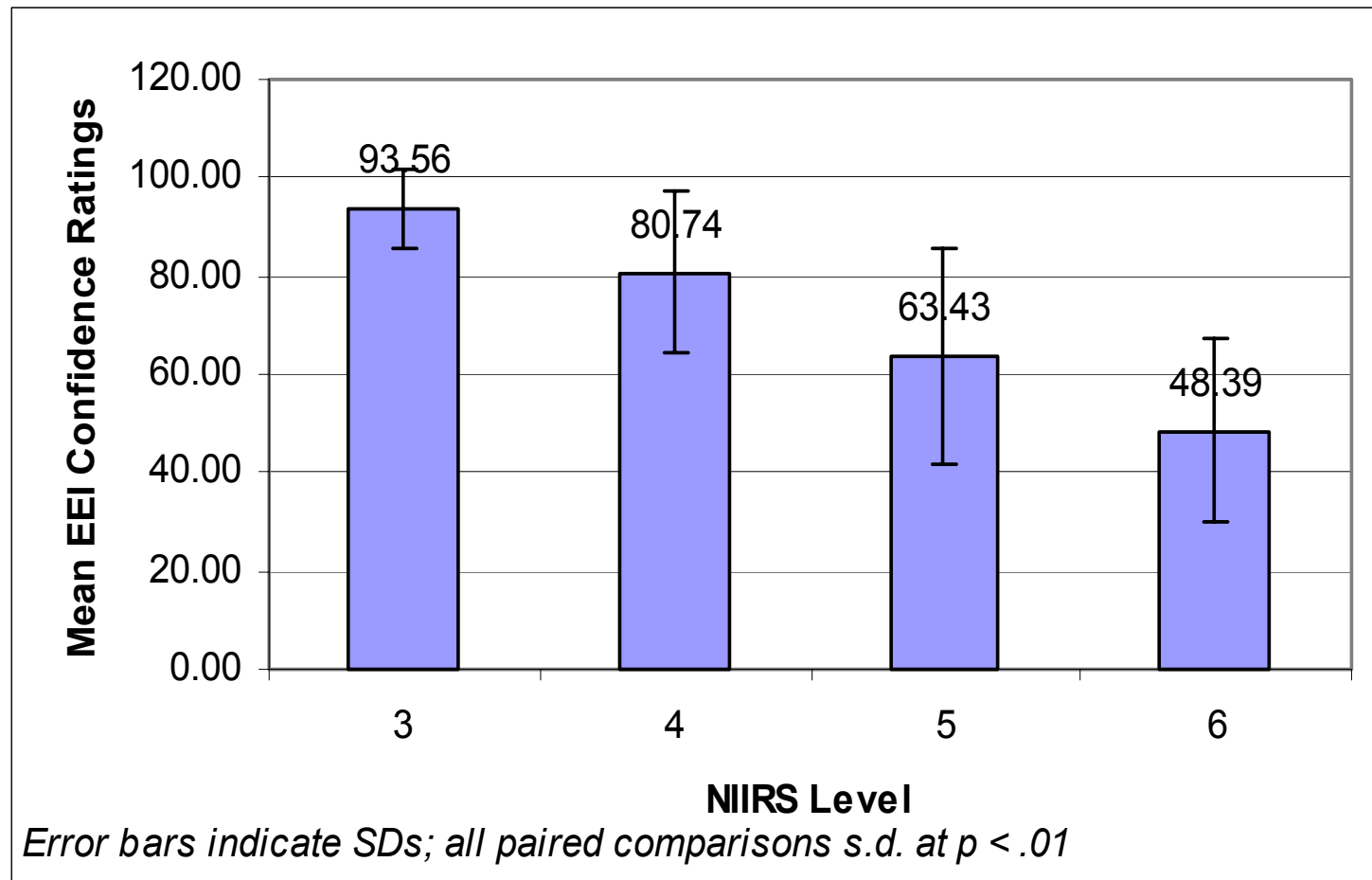
Pan EEI: TIFF vs. GeoTIFF

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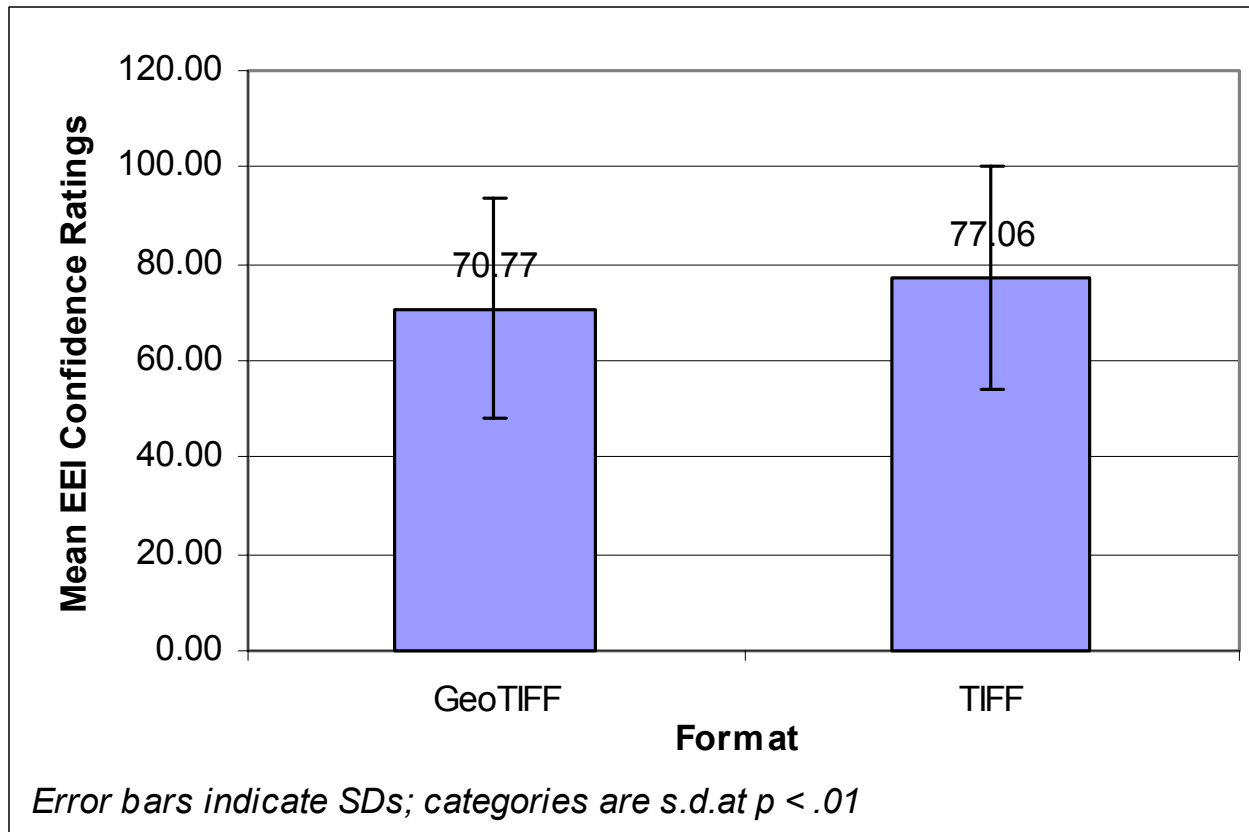
EEI Ratings by NIIRS Levels

Analysis: MSI/Pan-Sharpened

- Eleven IAs completed the MSI/Pan-sharpened evaluation over a 30 day period
  - 128 MS IIRS ratings
  - 601 confidence ratings of EEI tasks
- No outliers were identified
- Analysis of Variance (ANOVA)
  - Dependent variables
    - MS IIRS ratings
    - EEI confidence ratings
  - Independent variables
    - Climate
    - Image type (MSI vs. Pan-sharpened)
  - GSD was not used as an independent variable in the ANOVA
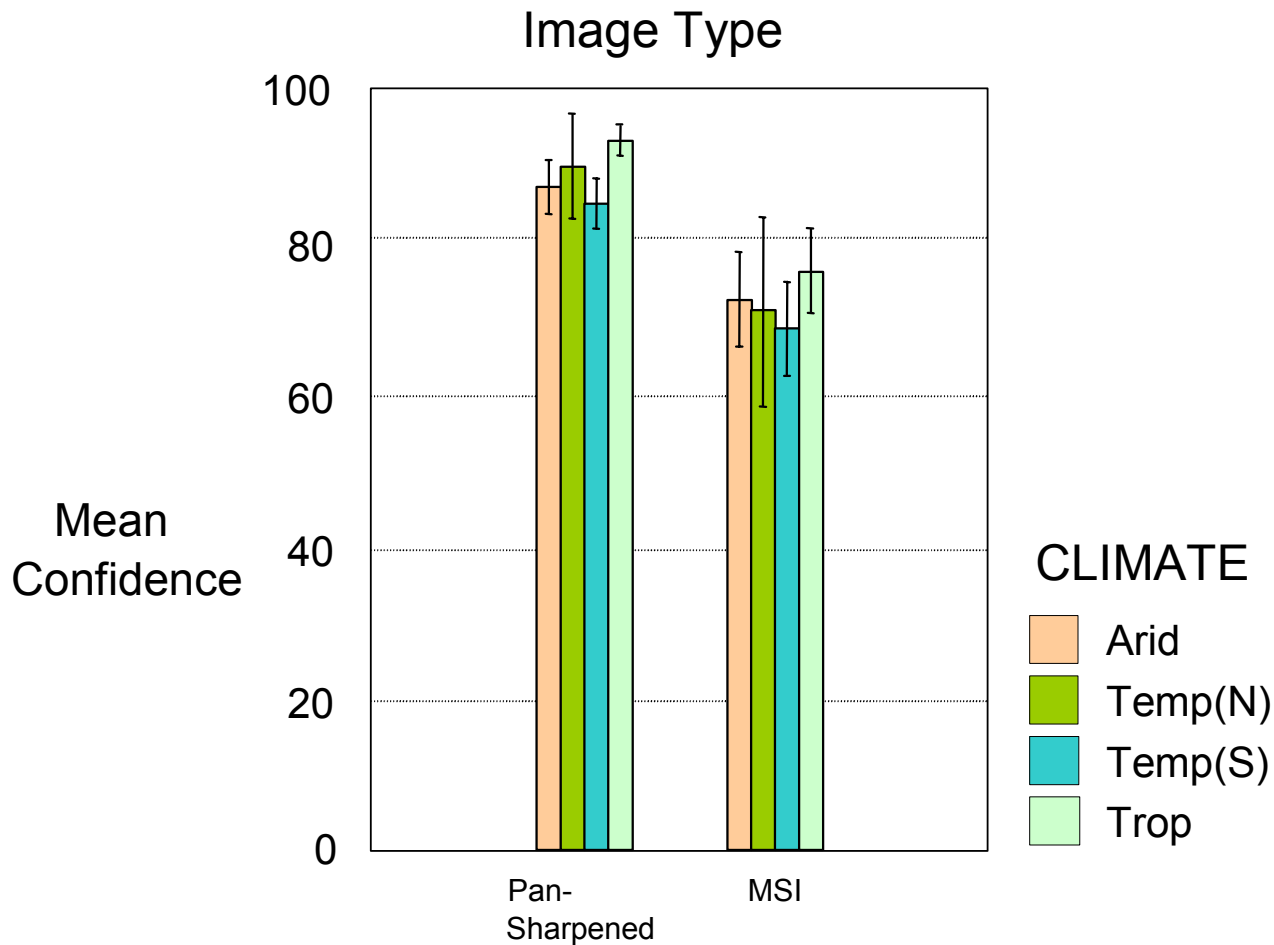   - Image type is linked to GSD

Mean MS IIRS

6.00
5.30
5.00
Mean 4.00
MS IIRS
3.94
3.00
2.00
1.00
0.00

MSI   Pan-sharpened
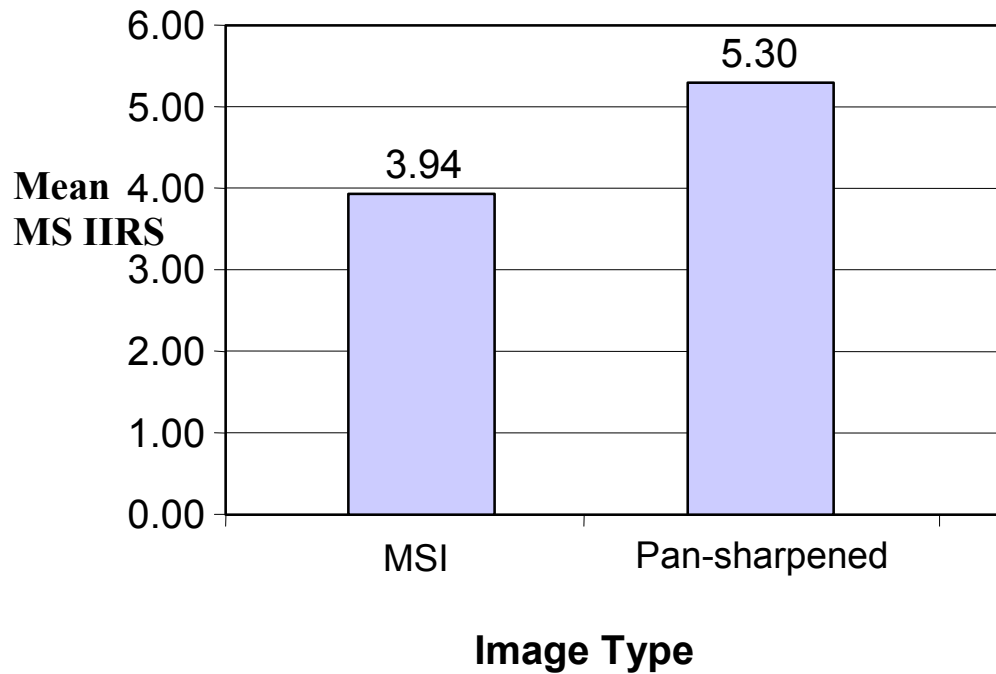
Image Type

MSI/Pan-sharpened EEI

Conclusions

- Image type was the most reliable indicator of performance
- GSD was found to be significant predictor of NIIRS/MS-IIRS and EEI performance for all image types
  - Level of processing was not found to be a significant predictor of NIIRS in the sample size used
  - High-resolution Panchromatic and Pan-sharpened MS products had higher ratings than the MSI products
- Not possible to fit IQE-like equations to predict NIIRS with great accuracy
  - Limited range of GSDs (0.8 to 1.3 meters)
  - IQE for two formats had statistically different slopes
    - Broken line IQE is more appropriate for the GeoTIFF images
    - Such a model could not be distinguished from a single linear equation with the data available

Conclusions

- Pan imagery is the preferred IKONOS product for imagery interpretation and intelligence task satisfaction
  - TIFF image format is recommended for intelligence EEI type application if the user has the option
- Pan-sharpened MS imagery can potentially perform as well as Pan imagery in interpretability tasks
  - Sharpened product must degrade the spatial and spectral information to some degree
  - Space Imaging disclaims the use of its Pan-sharpened MS imagery for spectral analysis

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